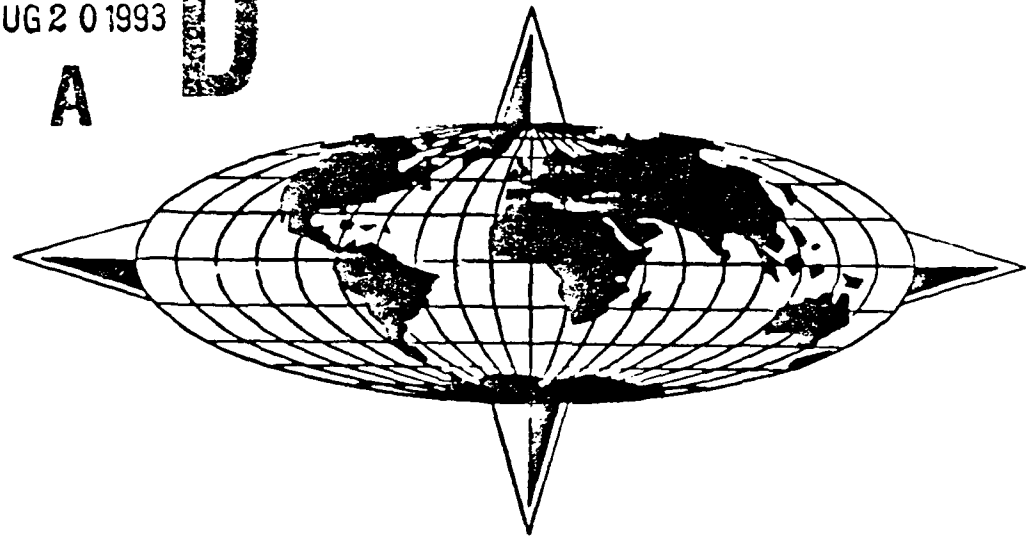
# ECDIS '92

## THE FIRST ANNUAL CONFERENCE AND EXPOSITION FOR ELECTRONIC CHART DISPLAY AND INFORMATION SYSTEMS





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The Defense Mapping Agency (DMA) has tasked the Naval Oceanographic and Atmospheric Research Laboratory (NOARL) to develop a product specification for a Digital Nautical Chart (DNC) database. The DNC will be used by the Department of Defense in nautical Electronic Chart Display and Information Systems. This paper will describe the structure and content of the DNC database.

The DNC data base will be implemented in DMA's Vector Product Format (VPF). VPF is a generic geographic data model designed to be used with any geographic data model in which vector data can be represented using nodes, edges, and faces. VPF is based upon the georelational model, combinatorial topology, and set theory. VPF is a new data model, upon which only prototypes of the Digital Chart of the World and Digital Terrain Data databases have been produced.

The DNC database will use DMA's Feature and Attribute Coding Standard to describe chart data and will include all features now found on paper Harbor, Approach and Coastal charts. Additional data may be included to support Navy requirements. The DNC will be a seamless, tiled database.

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# Digital Nautical Chart

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**ABSTRACT**

The Defense Mapping Agency (DMA) has tasked the Naval Oceanographic and Atmospheric Research Laboratory (NOARL) to develop a product specification for a Digital Nautical Chart (DNC) database. The DNC will be used by the Department of Defense in nautical Electronic Chart Display and Information Systems. This paper will describe the structure and content of the DNC database.

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The DNC database will use DMA's Feature and Attribute Coding Standard to describe chart data and will include all features now found on paper Harbor, Approach and Coastal charts. Additional data may be included to support Navy requirements. The DNC will be a seamless, tiled database.

The initial use of the DNC will be in the Navigation Sensor System Interface (NAVSSI) now being developed by the Naval Sea Combat Systems Engineering Station in Norfolk, Virginia and the Naval Air Development Center in Warminster, Pennsylvania. The goal of NAVSSI is for the electronic chart to replace the paper chart as a legal means of ownship navigation plotting. NOARL has worked closely with the NAVSSI project in the development of DNC specifications.

A draft DNC product specification was completed by NOARL in September 1991. An early prototype database covering two charts in the Norfolk, Virginia, area was produced by DMA in late 1991, and will be followed by a second prototype in early 1992. This second prototype will cover four charts in the Norfolk area and

will conform to the final VPF specification which is expected to be released in January, 1992.

## INTRODUCTION

As the Navy's lead laboratory in Mapping, Charting and Geodesy, the Naval Oceanographic and Atmospheric Research Laboratory (NOARL) was tasked by the Defense Mapping Agency (DMA) to develop a draft product specification for a Digital Nautical Chart (DNC) database. This paper describes the DNC database design, intended use, and prototype production schedule as of late 1991.

The DNC database is intended to be used in the Navigation Sensor System Interface (NAVSSI) aboard U.S. Navy ships. The NAVSSI project is a new system being designed with two primary objectives; processing/distribution of navigation data and the display/operation of electronic charts. NAVSSI will be the Navy's Electronic Chart Display and Information System (ECDIS). The goal of NAVSSI is to replace paper charts as a legal means of ownship navigation plotting.

The DNC will be a seamless, vector database distributed on CD-ROM. DNC will eventually provide world-wide coverage at every scale now used for marine navigation. In order to serve as a legal replacement for paper charts, the database will include all features currently shown on National Ocean Service (NOS) and DMA charts.

The DNC is implemented in DMA's Vector Product Format (VPF). VPF is an evolving standard, intended to be a general, user-oriented data format for representing large spatially referenced (geographic) databases. The DNC is expected to be produced by DMA, and so was designed to take advantage of DMA's existing production facilities.

## VPF OVERVIEW

Vector Product Format is intended to be a standard format for DMA's production and distribution of vector data. VPF uses a georelational data model to provide an organizational structure for any digital geographic database in vector format. VPF establishes a standard data model and organization, providing a consistent interface to data content. The DNC product specification determines the precise data contents of feature tables and their relationships.

A VPF database is composed of tables and directories that form a layered model. A VPF table is the organizational structure for all data content in VPF and consists of the following parts: a table header, which contains metadata about the table and the column definitions; the table contents, which contain the actual rows that make up the table; and a row id.

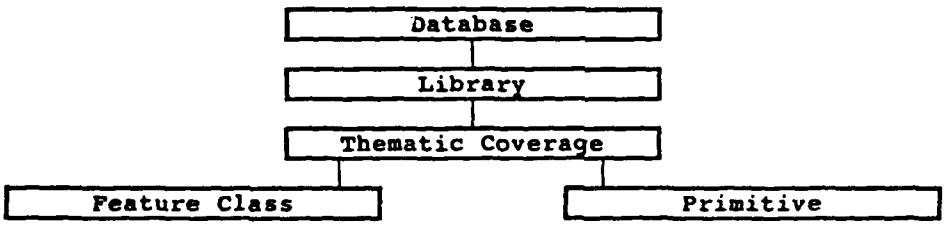
Figure 1 depicts a schema that defines the principal structure of any table in VPF.

Figure 1. VPF Table Structure

| Table Header | |
|---|---|
| Metadata and column definitions:<br><br>a. Table Description<br>b. Narrative File Name (optional)<br>c. Column Definitions:<br>column name<br>column text description<br>field type<br>key type<br>value description table name (optional) | |
| **ID** | **Table Contents** |
| Indicates the starting position of each row. | Data matching the column definitions. |

Figure 2 depicts the relationships between databases, libraries, coverages, feature classes and primitives in VPF. A collection of libraries makes up the database while a collection of thematic coverages makes up each library. Databases and libraries are used primarily to help organize data access, whereas coverages are used to define the relationships between features. Topology is incorporated at the coverage level to define spatial relationships between features. Since topology is present only at the coverage level, this presents difficulties in determining thematic coverage contents for the DNC. Geometric and cartographic primitives are at the lowest level. These primitives define the spatial aspects of entities. Also at this level are feature classes, which contain thematic information that helps apply meaning to the primitives. Both feature classes and primitives make up the thematic coverages.

Figure 2. VPF Layers



A database is a collection of related libraries plus additional tables which define data that is common to all of the libraries.

A library is a collection of coverages which share a single coordinate system and scale, have a common thematic definition, and are contained within a specified spatial extent. All of the tables and coverages making up the library are contained within a single directory.

At the database and library levels, various tables are required to define the database geographic extent, sources, accuracy, security, etc. At the thematic coverage level feature tables, value description tables, and primitive tables define features and attributes along with their spatial relationships.

A coverage is a set of feature classes (consisting of primitive and attribute tables) whose primitives interconnect according to coverage topology. A coverage is analogous to a single map sheet in conventional cartography. At this level, features are represented by a set of one or more primitives plus a row of attribute data. Every feature will have one primary row in a feature table that uniquely identifies it. Value description tables (VDT) relate the possible numeric or character values contained in the feature table to possible attributes for the features.

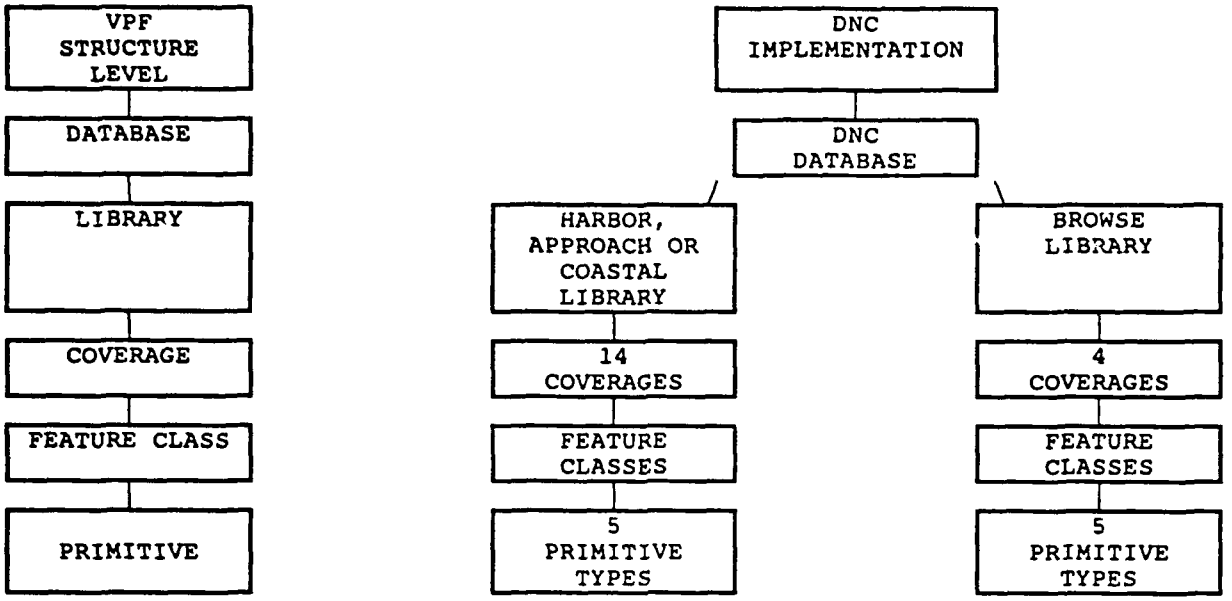
VPF defines three geometric primitive types; faces, edges, and nodes. The primitive tables contain the actual latitude and longitude values of the faces, edges, points or text comprising the feature. Index tables are used to decrease access times for variable length files.

**DNC IMPLEMENTATION**

The DNC database is implemented in VPF and will be distributed on CD-ROM. The DNC is based on the feature content of the paper Harbor, Approach and Coastal charts produced by DMA and uses the Feature Attribute Coding Standard (FACS) to define features, attributes, and attribute values. FACS is a military standard now used by DMA in digital production of paper charts. Figure 3 shows the VPF structure levels and DNC implementation.

The database directory level contains the database header table and the library attribute tables. The database header table contains the database name, originator, security classification and other information concerning the database. The library attribute tables contain the library names and geographic extent of the libraries.

Figure 3. VPF structure levels and DNC implementation




The DNC database is divided into libraries based on source chart scale. Since traditional paper nautical charts are not produced in standard sizes or scales, the DNC groups paper chart sizes into four scale bands and uses an equal-area tiling scheme (see Figure 4). The lower left (southwest) corner of each tile is identified using the World Geographic Reference System (GEOREF). This system divides the earth into quadrangles or tiles, the sides of which are specific arc lengths of longitude and latitude. The GEOREF identifier is used as the filename in the appropriate library of the database.

Figure 4. DNC libraries and tile sizes

| ID | LIBRARY (chart type) | TILE SIZE | CHART SCALES |
|---|---|---|---|
| A | GENERAL | 2.5° | < 1:500,001 |
| B | COASTAL | 45' | 1:75,000 to 1:500,000 |
| C | APPROACH | 7.5' | 1:25,000 to 1:100,000 |
| D | HARBOR | 7.5' | 1:10,000 to 1:50,000 |

The library directory level includes a library header table, a coverage attribute table and a geographic reference table. The library header table contains information identifying the contents, extent, projection, units, security source, and data

quality of the library. The coverage attribute table contains an ID, coverage name, description, and topological level for each coverage within the library. The geographic reference table includes four subrecords that define the geographic parameters of the library. These subrecords are: geographic parameters, projections, registration points, and diagnostic points.

In addition to the these libraries, the DNC will include a BROWSE library containing original paper chart boundaries, data quality information, coastline, major ports and CD-ROM coverage information.

The DNC is divided into 14 thematic coverages. These coverages are shown in figure 5. (Coverage names are subject to change).

Figure 5. DNC thematic coverages

| COVERAGE NAME | DESCRIPTION |
|---|---|
| cultural landmarks | man-made features on land of interest to marine navigation |
| earth cover | shoreline, foreshore, open water, etc. |
| inland water | inland shoreline, lakes, ponds, etc. |
| land cover | vegetation, snow, ice, etc. |
| relief | elevations on land |
| port facilities | berths, piers, etc. |
| obstructions | rocks, wrecks, etc. |
| aids to navigation | buoys, lights, etc. |
| hydrographic | depths, bottom characteristics, etc. |
| environment | tides, currents, magnetic variation, etc. |
| general info limits | Colregs demarcation, custom boundary, etc. |
| caution limits | Work in Progress area, etc. |
| avoidance limits | prohibited area, restricted area, etc. |
| navigation limits | channel limits, traffic separation zone, etc. |

Within each coverage are feature tables for each feature class (area, line, point and text) and corresponding primitive tables. A sample line feature table is shown in figure 6. This table contains FACS codes for each feature within the coverage, related feature attributes, and a key into the associated primitive table. Figure 7 shows an integer value description table which relates integer values found in the feature table to actual attribute values. A sample edge primitive table for line features is shown in figure 8.

Figure 6. Partial hydrography line feature table.

```
{Header length};\
HYDLINE.LFT, Hydrography Line Feature Table;-;\
ID=I,1,P,Row ID,-,:\
F_CODE=T,5,N,FACS Code,CHAR.VDT,:\
ACC=I,1,N,Accuracy Category,INT.VDT,;
CRV=I,1,N,Depth Curve or Contour Value,INT.VDT,;
UNI=I,1,N,Units Category,INT.VDT,;
VDC=I,1,N,Vertical Datum Category,INT.VDT,;
VDR=I,1,N,Vertical Datum Record,INT.VDT,;
```

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2E010 | 1 | 10 | 1 | 1 | 1 |
| 2 | 2E010 | 1 | 10 | 1 | 1 | 1 |
| 3 | 2E010 | 1 | 20 | 2 | 1 | 1 |
| 4 | 2E010 | 1 | 20 | 2 | 1 | 1 |
| . | . | . | . | . | . | . |

Figure 7. Partial hydrography integer value description table

```
{Header length};\
INT.VDT, Hydrography Integer Value Description Table;-;\
ID=I,1,N,Row ID,-,:\
TABLE=T,12,F,Feature Class Table Name,-,:\
ATTRIBUTE=T,10,F,Attribute Name,-,:\
VALUE=T,5,F,Attribute Value,-,:\
DESCRIPTION=T,50,F,Attribute Value Description,-,;
```

| | | | | |
|---|---|---|---|---|
| 1 | HYDLINE.LFT | ACC | 001 | Accurate |
| 2 | HYDLINE.LFT | ACC | 002 | Approximate |
| 3 | HYDLINE.LFT | ACC | 003 | Doubtful |
| 4 | HYDLINE.LFT | EXS | 001 | Definite |
| 5 | HYDLINE.LFT | EXS | 002 | Doubtful |
| 6 | HYDLINE.LFT | EXS | 003 | Reported |
| 7 | HYDLINE.LFT | HDI | 009 | Depth Known by Other Than Wire |
| . | . | . | . | . |

Figure 8. Schema for edge primitive table.

| Column name | Column name description |
|---|---|
| ID | The row id primary key |
| *.LFT_ID | Line feature table id |
| START_NODE | Start node foreign key to entity node table |
| END_NODE | End node foreign key to entity node table |
| RIGHT_FACE | Right face foreign key to face primitive table |
| LEFT_FACE | Left face foreign key to face primitive table |
| RIGHT_EDGE | Right edge foreign key to following edge |
| LEFT_EDGE | Left edge foreign key to following edge |
| NEXT_EDGE | Next edge in a line network, foreign key to edge primitive |
| COORDINATES | Edge coordinates |

## DNC PROTOTYPE PRODUCTION

The Environmental Systems Research Institute, Inc., (ESRI) in Redlands, California, is producing the DNC prototype for DMA. Three prototypes are planned.

Prototype 1A is expected in late November 1991. It will contain two 5' by 5' subsets extracted from data that has been digitized by ESRI for DMA's Digital Chart of the World (DCW) Prototypes 2 and 3. These data will be converted to VPF and distributed on floppy disk. Prototype 1A will use the DCW attribute codes, however, rather than the DNC FACS codes.

Prototype 1B is expected in late January 1992. It will be structured in VPF and will contain the full data sets digitized for DCW Prototypes 2 and 3. Prototype 1B will utilize FACS codes for attribute definition and will be distributed on magnetic tape.

Prototype 2 is expected in late April, 1992. It will contain six charts of the Norfolk area; one at the Coastal scale, two at the Approach scale, and three at the Harbor scale. Prototype 2 will conform completely to the DNC product specification and will be distributed by DMA on CD-ROM.

The Naval Sea Combat Systems Engineering Station plans to evaluate the DNC database in the NAVSSI system on board an aircraft carrier in the late summer of 1992.

**ISSUES**

Several issues remain concerning the final design of the DNC database. It is hoped that most of these will be resolved during the prototyping process.

- VPF specifies "little-endian" byte-order as the data storage format. This will require most Unix workstations (which use "big-endian" format) to allocate CPU time for byte-swapping whenever data is read into the system. If performance degradation in Navy systems proves to be significant, it may be necessary to modify the DNC product specification to specify "big-endian" byte ordering.

- The use of FACS may present problems in efficiently representing the feature content of NOS paper charts. NOS produces charts of U.S. waters, while DMA produces charts of foreign waters. Since the NOS and DMA charts are produced using different methods, it may be necessary to develop new FACS codes to represent features which are present on NOS charts, but not on DMA charts.

- It is sometimes difficult to adequately represent overlapping or coincident polygons within the same thematic coverage using FACS codes and VPF/DNC constraints. This has required the subdivision of some coverages in the DNC into numerous smaller coverages, with a resulting decrease in topologic information and an increase in system overhead. It remains to be seen if the numerous coverages will present problems to the mariner.

- It is not yet clear what data volumes may be expected when storing nautical charts in VPF format. The data density required to adequately represent features on the NAVSSI screen has not yet been addressed. Current requirements for digitizing paper charts are based on production of new paper charts, rather than an ECDIS, and may not be appropriate for electronic charts.

- The matter of chart marginalia has not yet been resolved. As several paper charts are digitized and merged into one seamless database, how and when does one present chart marginalia? Which margin notes will apply to which portions of the electronic chart?

- How should text that is not directly associated with any specific feature (such as "Gulf of Mexico" or "Shoaling") be stored? A bounding rectangle would allow the area to be queried by a user, but a bounding rectangle may be impossible to define. If the text is associated with a specific point, it may be lost when the area that is to be displayed covers only a portion of the feature.

- The issue of chart updates has not been resolved. Although the weekly production of new CD-ROMs to reflect the

Weekly Notice to Mariners may seem cost effective, it is not satisfactory for units that are deployed at or under the sea for long periods of time. The distribution of chart updates by electronic message and/or floppy disk as an additional thematic coverage may be feasible, but many technical issues remain unresolved.

## CONCLUSION

The Digital Nautical Chart will provide the U.S. Navy with a standard vector database for marine navigation, mission planning, and tactical and strategic operations. Several issues remain concerning DNC, including data format, the determination of thematic coverages, storage and representation of cartographic text and marginalia, and chart updates. However, with the production of several DNC prototypes and the deployment of the Navigation Sensor System Interface by mid-1992, the Navy will be well on the way to fielding an effective ECDIS.

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